that the arrangement of the magnetism during the time that the electric current traversed the helix, appeared not to be the same as after the cessation of that current; in the one case similar, and in the other dissimilar, poles being opposed to each other at the opposite extremities of the two semi-circles.

Whether the magnetism was originally developed in the soft iron by means of an electric current passing round it, or by passing over its surface the poles of an electro-magnet, or those of a common magnet of hard steel, it appeared to possess the same power of retaining a large portion of the magnetism thus developed. The retention of the magnetism does not appear to depend upon the relative positions of the ends of the horse-shoe and the keeper remaining undisturbed, but on their contact remaining unbroken: for one keeper was substituted for another without diminution of this power; care being taken that the second should be in good contact with both ends of the horse-shoe before the complete removal of the first.

This power of soft iron to retain the magnetism developed in it was also shown by the action of the ends of the horse-shoe magnets upon a magnetized needle; by the attraction of iron filings; and by the evolution of the electric spark, by means of a suitable apparatus, on the sudden rupture of the contact between the keeper and the horse-shoe, when several days had intervened since the removal of the battery by which the magnetism had been originally developed.

The author's views on entering upon these experiments were, that the soft iron, with its keeper, resembled a closed voltaic circuit; but they have convinced him that the phenomenon of the permanency of the magnetism resolves itself into a case of complex induction, between the soft iron horse-shoe and the keeper.

May 2, 1833.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G., President, in the Chair.

The Right Honourable the Earl of Darnley was elected a Fellow of the Society.

A paper was read, entitled, "Essay towards a first approximation to a Map of Cotidal Lines." By the Rev. William Whewell, M.A. F.R.S. Fellow of Trinity College Cambridge.

The general explanation of the phenomena of the tides originally given by Newton, although assented to by all subsequent philosophers, has never been pursued in all the details of which its results are susceptible, so as to show its bearing on the more special and local phenomena, to connect the actual tides of all the different parts of the world, and to account for their varieties and seeming anomalies. The first scientific attempt that was made to compare the developed theory with any extensive range of observations, was that of Daniel Bernouilli in 1740: the subject has since been pursued by Laplace and Bouvard, and still more recently by Mr. Lubbock. But

the comparison of contemporaneous tides has hitherto been unaccountably neglected: and to this particular branch of the subject the researches of the author are in this paper especially directed; the principal object of his inquiry being to ascertain the position of what may be called *cotidal lines*, that is, lines drawn through all the adjacent parts of the ocean where it is high water at the same time; as, for instance, at a particular hour on a given day. These lines may be considered as representing the summit or ridge of the tide wave existing at that time, and which advances progressively along the sea, bringing high water to every place where it passes. Hence the cotidal lines for successive hours represent the successive positions of the summit of the tide wave, which in the open sea travels round the earth once in twenty-four hours, accompanied by another at twelve hours' distance from it, and both sending branches into the narrower seas. Thus a map of cotidal lines may be constructed, at once exhibiting to the eye the manner and the velocity of all these motions.

Although the observations on the periods of the tides at different places on the coast and different parts of the ocean, which have been at various times recorded, are exceedingly numerous, yet they are unfortunately for the most part too deficient in point of accuracy, or possess too little uniformity of connexion to afford very satisfactory results, or to admit of any extended comparison with theory. With a view to arrive at more correct conclusions, the author begins his inquiry by endeavouring to determine what may be expected to be the forms of the cotidal lines, as deduced from the laws which regulate the motions of water: and he proceeds afterwards to examine what are their real forms, as shown by the comparison of all the tide observations which we at present possess.

The paper is divided into five sections. In the first the author treats of cotidal lines as deduced theoretically from the known laws of the motion of fluids. On the supposition that the whole surface of the globe is covered with water, the cotidal lines would coincide with the meridians, and would revolve round the earth from east to west in something more than twenty-four hours, with a velocity of nearly 1000 miles an hour at the equator. The form and the regularity of these lines would be materially affected by the interposition of land in different parts of this ocean, whether in detached islands, or groups of islands, or large continents, occupying a considerable portion of the surface. In these cases the primary wave will be broken, deflected and variously modified, so as to give rise to secondary or derivative tides, sometimes separating into branches, and producing points of divergence; sometimes uniting at various places, or points of convergence; and at other times producing, by more complex combinations, various phenomena of interference, and other apparently anomalous results. Such is the general character of the tide-waves that actually proceed along the coasts of the Atlantic: and the modifications in their course and velocity are still more perceptible in bays, gulfs, and narrower channels and inlets of the sea, as well as in their progress along rivers. The author traces in detail the effects which these different circumstances may be expected to produce. He adverts to an important distinction which has frequently

been lost sight of, between the progressive motion of the tide-wave and the actual horizontal motion of the water, or tide-current; motions which do not bear any constant relation to one another. Hence the change in the direction of the current does not invariably indicate the rise or fall of the water.

In the second section he examines the causes which have led to inaccuracy in making observations on the tides; the first of which is dependent on the circumstance just mentioned, of the occasional want of correspondence between the times of *high* and of *slack* water; the former referring to the moment of greatest elevation, the latter to that when the direction of the current changes. The other causes of error are derived from the change which takes place in the course of the day in the moon's angular distance from the sun; from the half-monthly inequality in the establishment, arising from the relative position of the sun and moon during each lunation; and from the necessity that exists of making a correction for what may be termed the *age* of the tide; that is, the interval of time which has elapsed between the period of the origin of the wave and the time of its actual arrival at the place of observation.

The third section, which forms the chief bulk of the paper, is occupied by a statement and discussion of the tide observations now extant, and which the author has, with great industry, collected from a variety of sources, both of published accounts, and of manuscript documents preserved in the Admiralty. Commencing with the tide-waves, first of the eastern and then of the western coasts of the Atlantic, he follows them to the Northern sea, and to the different coasts of the British islands, and of the German Ocean. He passes next to the examination of those of the Southern Atlantic at Cape Horn and the adjacent coasts; thence tracing them, as far as the present imperfect data will allow, along the western shores of the American continent, to the central parts of the Pacific, and in their progress across the Australian and Indian Oceans. He likewise examines the condition of the tides in rivers, as to the magnitude and velocity of the undulations, the occasional production of a high and abrupt wave, or *bore*, and as to the influence of the natural stream of the river upon the different periods of elevation or depression of the water.

The fourth section contains general remarks on the course of the tides, suggested by the preceding review of the phenomena they present; on the velocity of the tide-wave; on the form of the cotidal lines; on the currents which attend the tides; on the production of revolving currents; on the magnitude of tides; and on the constancy of the cotidal lines. He adverts also to some peculiarities resulting from interference, such as the differences of the two diurnal tides, and occasionally the occurrence of single day tides.

In the concluding section the author offers various suggestions respecting the most eligible mode of making observations on the tides, and of correctly reducing them when made.